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L7: Entry 7 of 13   File: USPT   Oct 20, 1998

DOCUMENT-IDENTIFIER: US 5824607 A
TITLE: Plasma confinement for an inductively coupled plasma reactor

BSPR:
The present invention provides a plasma enhanced CVD chamber having an antenna driven by RF energy (LF, MF, or VHF) and one or more magnets to provide a magnetic field in the chamber to confine or guide the electrons and ions generated by the source in the chamber. The RF energy is inductively coupled inside the reactor dome to provide a plasma source. In one aspect of the invention, CVD processing gases are introduced into the chamber by a gas inlet ring and the chamber pressure is maintained by a gas control system employing a throttle valve and a gate valve and a turbo molecular pump. The antenna generates a high density, low energy plasma inside the chamber for deposition or etching of metals, dielectrics and other materials. The process proceeds in two distinct phases. First, a reactive plasma is generated by the antenna and the material is directed towards the wafer to be processed. As a byproduct of this step, material is deposited on certain areas of the chamber walls. Second, a distinct cleaning plasma, usually <u>fluorine</u> based, is generated in the chamber, or pumped into the chamber from a remote plasma source, and is directed by one or more magnetic fields towards the areas of where residue build-up occurs, and away from the wafer pedestal. Plasma confinement and direction during the cleaning phase is facilitated by use of externally generated magnetic fields. This produces an enhanced chamber cleaning technique which can considerably improve system throughput by confining or guiding the plasma flux to areas of heavy build-up, thereby increasing the efficiency of the cleaning process.

DEPR:
The evacuation of the interior of the chamber housing 11 is controlled by a throttle valve 18 on a vacuum line 19 which connects to a vacuum pumping system 21 having one or more vacuum pumps such as a <u>turbomolecular</u> pump.

CLPV:
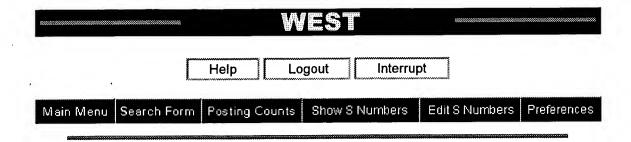(<u>f</u>) generating a repelling magnetic field to repel the plasma flux from the substrate support member.

CLPV:
(<u>f</u>) a controller for selectively activating the magnet during a cleaning process.

CCXR:
<u>134/1.1</u>

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134/$	0
134/1.USPT.	1201
134/10.USPT.	860
"134/100.1".USPT.	206
"134/102.1".USPT.	443
"134/102.2".USPT.	184
"134/102.3".USPT.	111
"134/103.1".USPT.	231
(TURBOMOLECULAR AND ((134/$)!.CCLS.)).USPT.	20

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Refine Search:

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16 and (f or fluorine or nf)
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Clear

Search History

Today's Date: 1/27/2002

DB Name	Query	Hit Count	Set Name
USPT	turbomolecular and ((134/$)!.CCLS.)	20	L6
USPT	l3 and ((134/$)!.CCLS.)	3	L5
USPT	l3 and ((438/905)!.CCLS.)	0	L4
USPT	l1 same clean$	71	L3
USPT	l1 and clean$	431	L2
USPT	turbomolecular pump	870	L1

5 904 469

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End of Result Set

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L7: Entry 13 of 13   File: USPT   Apr 11, 1989

DOCUMENT-IDENTIFIER: US 4820377 A
TITLE: Method for cleanup processing chamber and vacuum process module

DEPR:
An elevator drive motor 32 provides the elevation of the transfer arm 28, and the arm drive motor 34 provides the extension and retraction of the transfer arm 28. Neither of these motors requires a vacuum feedthrough since they are housed inside the exhaust manifold 36. The manifold 36, as shown in FIG. 1, has a cylindrical shape and extends from the bottom of chamber 12 downward. The manifold also extends through and is attached to the bottom of chamber 12 a short distance into chamber 12. The pump 38 is at the end of manifold 36 away from its attachment to chamber 12. The motor 26 also extends downward from chamber 12. Pump 38 can be, for example, a turbomolecular pump. The exhaust manifold 36 does not open directly into the vacuum load lock chamber 12, but instead has apertures 40 around its top (the end of manifold 36 extending into chamber 12). Thus, the exhaust manifold 36 is configured so that there is not a line of sight path from the elevator drive motor 32, the arm drive motor 34, or from the pump 38 to the vacuum load lock chamber 12. This reduces ballistic transport of particulates from these moving elements into the load lock chamber. The arrangement shown in FIG. 1 has been found useful but other arrangements are possible to provide the necessary transportation of the wafer 48.

DEPR:
One class of embodiments disclosed herein provides a deglaze process wherein the activated products of a source gas flow which includes both a fluorine source gas species or, alternatively, anhydrous HF and also a large percentage of oxygen are flowed across a wafer surface downstream from a plasma discharge which is remote from the wafer surface. This embodiment has the advantages that a dry deglaze process which does not selectively erode silicon is provided. This embodiment has the further advantage that a deglaze process is readily combined sequentially with a following process step. For example, an in situ deglaze can be used to remove native oxides, and assure a clean interface for succeeding deposition steps. The process module 570 shown in FIG. 9 can be used without actuating the ultraviolet light or in the alternative another process module could be constructed without the space 220, ring 576, and the other components associated with the production of ultraviolet light in space 220.

DEPR:
In the embodiment shown in FIG. 9, the quartz outlet tube 256 is connected to the third gas feed 250, like that shown in FIG. 14 by a non-contact slip fit joint 258. This loose slip fit will permit some of the gas feed to leak out directly into the exhaust space during processing, but this is only a minor problem. The advantage of using a slip fit here is that it accommodates the vertical motion of the process chamber while still permitting essentially the whole path of the gas flow from the remote plasma chamber 254 to be conducted through quartz tubing. As discussed above, the vertical motion serves to open and close the process chamber for wafer insertion and removal. This has been found to be a useful feature in practice since many of the activated species generated by the remote plasma will be very active. These active species include radicals such as Oxygen, quasi-stable molecular species such as oxy-halogen compounds, molecules in quasi-stable states with high electron energies, and especially close to the plasma, a significant fraction of ionized species. The tube used to carry this flow should be both as inert as possible in order to resist attack and be s pure as possible to minimize contamination of the wafer by species which may be removed from the tube walls by the flow of the activated species. Quartz meets

both of these criteria for most sources. If the gas flows to be used include
fluorine sources the tubing can be made of sapphire, or sintered alumina or
copper. Additionally, depending on the process chemistries used, it may be
simpler to use quartz if the erosion of the quartz outlet tube 256 and the
modification of the chemistry in the gas flow can be tolerated in the particular
process being run.

DEPR:
FIG. 16 shows details of another process module 630 which in many respects is
similar to that shown in FIG. 14. A wafer 48 is held against a conductive
susceptor 300 which may be of aluminum or optionally of silicon if it is useful
to modify the process chemistry (e.g. to create a fluorine-deficient plasma near
the wafer face 54. The susceptor 300 is located above the wafer 48 with the top
chamber 218 located between the wafer 48. The susceptor 300 is cooled by passages
302. If desired susceptor 300 can be heated through passages 302 or by utilizing
heater rods (not shown) passing through susceptor 300. The wafer 48 is held
against susceptor 300 by the three support fingers 214 in FIG. 16 with its face
54 facing downward away from susceptor 300.

DEPR:
Such seals have been suggested for use in ultra high vacuum systems (which are
periodically baked out, at temperatures of, e.g. 600 degrees F.) as indicated in:
I. Sakai et al., "Sealing Concept of Elastic Metal Gasket `Heliocflex`", 32
Vacuum 33 (1982); Hajime Ishimaru et al., "Bakable Aluminum Vacuum Chamber and
Bellows with an Aluminum Flange and Aluminum Seal for Ultra High Vacuum", 226
IEEE Transactions on Nuclear Science 4000 (1979): R. B. Fleming et al.,
"Development of Bakable Seals for Large Non-Circular Ports on the Tokamak Fusion
Test Reactor", 17 Journal of Vacuum Science and Technology 337 (1980): Hajime
Ishimaru et al., "Bakable Aluminum Vacuum Chamber and Bellows with an Aluminum
Flange and Aluminum Seal for Ultra High Vacuum", 15 Journal of Vacuum Science and
Technology, 1853 (1978); all of which are hereby incorporated by reference.
Applicants believe that such seals were originally marketed for their ability to
tolerate high pressure differentials at relatively high temperatures (e.g. 600
degrees F.) and still maintain a vacuum seal, but it is not known that such a
seal has ever been suggested to provide a vacuum seal between two dissimilar
materials in rapidly changing temperature environments, nor specifically for
rapid thermal processing in vacuum processing systems.

DEPR:
A further advantageous use of the radiant heating capability in this embodiment
is to enhance removal of residues from the chamber walls. For example, a very
efficient chamber cleanup can be performed, after the wafer has been removed, by
heating the susceptor to a significantly higher temperature than the processing
temperature (e.g. 700 C.). Since the processing chamber is so small, the chamber
walls will all be at least somewhat thermally coupled to the susceptor by radiant
heat transfer. A feed gas which will produce very active dissociation products in
a plasma can be flowed in, and the combination of the high temperature and the
active species will remove residues very fast. Suitable feed gases would inlcude
a chlorine source such as BCl.sub.3, or a fluorine source such as SF.sub.6.

DEPR:
One class of processes which has shown very significant success in reactors of
the kind described above is anisotropic fluorine etches for materials including
refractory metals.

DEPR:
It has been found that a combination of a hydrocarbon with a bromine source, for
example, HBr or CF.sub.3 Br, provides a very potent passivating chemistry for
fluorine-based etches. A fluorine source such as SF.sub.6, NF.sub.3, HF, F.sub.2,
CF.sub.4, C.sub.2 F.sub.6, BF.sub.3 or SiF.sub.4 can be used for the
fluorine-based etch. For example, one embodiment which has been successfully
demonstrated is as follows: The starting structure included a thin film of
tungsten. Initial gas flows included 50 sccm of SF.sub.6, 5 sccm of CH.sub.4, and
15 sccm of HBr at a total pressure of 250 milliTorr and an applied RF power level
of 500 Watts. After the pattern had begun to clear, an additional flow of 20 sccm
of WF.sub.6 was added, as will be further discussed below. The resulting
structure showed nearly vertical etched sidewalls, only slight linewidth erosion,
and excellent selectivity to resist. In another process, a source of Fluorine
with WF.sub.6 acting as a load during overetch has been found to reduce line

width loss.

DEPR:
Another, alternative, family of chemistries for fluoro-etching uses a feed gas mixture which includes a <u>fluorine</u> source such as SF.sub.6) plus a bromine source, such as HBr, plus a very weak oxygen source (e.g., carbon monoxide). This chemistry provides anisotropic high rate fluoro-etching with good selectivity to photoresist.

DEPR:
Another alternative family of chemistries for fluoro-etching uses a feed gas mixture which includes a <u>fluorine</u> source (such as SF.sub.6) plus a fluorosilane (e.g., SiF.sub.4), plus a bromine source (such as HBr), plus a weak oxygen source such as carbon monoxide. This chemistry provides anisotropic high rate fluoro-etching with good selectivity to photoresist.

DEPR:
The process chemistry can alternatively consist of O.sub.2 plus one or more of the species: N.sub.2 O, H.sub.2 O, H.sub.2, CF.sub.4, CHF.sub.3, HCl, HBr, and Cl.sub.2. Of these, H.sub.2 is the most useful in some instances additive gas for the following reasons; (a) the N.sub.2 O additive does not enhance the rate as much as H.sub.2, particularly at lower temperatures; (b) halogen-containing gases present some risk of deleteriously affecting the metals present on the substrate. If this constraint were lifted, CF.sub.4 and CHF.sub.3 would be very good choices, because they could provide descum rates as much as one order of magnitude faster than H.sub.2. The remaining problem with CF.sub.4 and CHF.sub.3 is reactor materials-compatibility problems due to the presence of <u>F</u> atoms. This could be solved by using a Teflon (TM) showerhead.

DEPR:
Another process useful with process module 1300 is for the etch of ZnS or HgCdTe which form at least a part of a wafer. A gas mixture of a source of atomic <u>fluorine</u> mixed with a inert carrier such as Helium is utilized to generate a remote plasma. An in situ plasma is generated from at least the products of the remote plasma and an alkyl-bearing species. The powers used to generate the remote plasma and in situ plasma are separately controlled to produce improved etch rates. The remote and in situ plasmas produce an etch rate which is greater than the sum of the rates of in situ and remote plasmas used separately. Relative low power RF is used to generate an in situ plasma in conjunction with the remote plasma to provide an partially anisotropic etch with a relative high etch rate. Since the remote plasma and in situ plasma can be separately controlled, improved profile control and etch selectivities can be achieved. An in situ descum can be performed before the etch and a post-etch ashing utilizing a remote plasma formed from a source of oxygen. The alkyl-bearing process can be, for example, methane, ethane, mehtylfouoride, methylchlorides, methyliodide, or methylbromide. The source of atomic <u>fluorine</u> can be, for example, <u>fluorine,</u> CF.sub.4, SF.sub.6, NF.sub.3, C.sub.2 F.sub.6 or any other gaseous <u>fluorine</u> compound which releases its <u>fluorine</u> atoms in the presence of a plasma. The power used can be, for example, 250 watts or less for the RF and 400 watts for the MW. The flow rates can be 100 sccm for CF.sub.4, 125 sccm for Ch.sub.4, and 1000 sccm for Helium. The pressure can be, for example, 0.8 Torr. The surface damage is minimized while the etch rate is improved. The remote and in situ plasmas can be separately controlled. The resultant etch is partially anisotropic. The level of anisotropy can be controlled by the relative RF plasma and microwave power levels, as well as the pressure.

DEPR:
Another process useful with process module 1300 is for the etch of Silicon Nitride. A source of <u>Fluorine</u> and Helium were used with remote plasma and in situ plasma to produce improved etch rate over the sum of the rates of in situ and remote plasmas used separately. As an example, the RF power is 225 watts in the process chamber at an 13.56 MHz and the remote plasma generator is operating at 400 watts at 2450 MHz. The gases used were <u>fluorine</u> gas source, for example, CF.sub.4 at 200 sccm and Helium at 1000 sccm. Other sources of <u>Fluorine</u> can be F.sub.2, CHF.sub.3, C.sub.2 F.sub.6, SF.sub.6, or F.sub.3, singly or in any combination with CF.sub.4. The pressure can be 0.7 Torr and the temperature 25 degrees C. This process results in improved results because of a synergistic effect between the remote and in situ plasmas. These results were obtained even though they had not been optimized for the particular conditions used, but they

do show the synergistic advantage of combining these two effects. The surface damage is minimized while the etch rate is improved. The remote and in situ plasmas can be separately controlled. The resultant etch is partially anisotropic. The level of anisotropy can be controlled by the relative RF plasma and microwave power levels, as well as the pressure.

DEPR:
A further process useful with process module 1300 is for the etch of polysilicon. A source of Fluorine and Helium were used with remote plasma and in situ plasma to produce improved etch rates of twice the sum of the remote and in situ plasmas alone. As an example, the RF power is 225 watts in the process chamber at an 13.56 MHz and the remote plasma generator is operating at 400 watts at 2450 MHz. The gases used were fluorine gas source, for example. $CF.sub.4$ at 200 sccm and Helium at 1000 sccm. Other sources of Fluorine can be $F.sub.2$, $CHF.sub.3$, $C.sub.2$ $F.sub.6$, $SF.sub.6$, or $NF.sub.3$ singly or in any combination with $CF.sub.4$. The pressure can be 0.7 Torr and the temperature 25 degrees C. This process results in improved results because of a synergistic effect between the remote and in situ plasmas. These results were obtained even though they had not been optimized for the particular conditions used, but they do show the synergistic advantage of combining these two effects. The surface damage is minimized while the etch rate is improved. The remote and in situ plasmas can be separately controlled. The resultant etch of the polysilicon is partially anisotropic. The level of anisotropy can be controlled by the relative RF plasma and microwave power levels, as well as the pressure.

DEPR:
Another useful process is an overetch of a tungsten material (a layer) to achieve selectivity to silicon dioxide and the desired anisotropy. A source of Fluorine, which can be, for example, $CF.sub.4$, $C.sub.2$ $F.sub.6$, HF, $F.sub.2$, $NF.sub.3$, or $SF.sub.6$, a source of hydrocarbon, for example, $CH.sub.4$ and HBr are used. The hydrocarbon and HBr can be omitted but an improved etch is provided if they are present. The hydrocarbon performs a side wall passivant during the etch which reduces the line width loss. As an example, first, the bulk of the tungsten layer is etched using, for example, one of the tungsten etch processes discussed herein. After this step, the etching continues utilizing remote and in situ plasma under the following conditions as an example. The RF power is 50 watts in the process chamber at an appropriate frequency and the remote plasma generator is operating at 400 watts. The gases can be a fluorine gas source, for example, $SF.sub.6$, at 40 sccm, a bromine source, for example, HBr at 13 sccm, and a hydrocarbon source, for example, $CH.sub.4$ (methane) at 5 sccm. The pressure can be 0.13 Torr and the temperature 25 degrees C. This process results in improved results because of a synergistic effect between the remote and in situ plasmas which provides an increased selectivity to silicon dioxide and photoresist. The etch is also improved by allowing the separate adjustment of microwave (MW) and radio frequency (RF) power during the plasma generation. The pressure should be from about 0.1 Torr to about 5 Torr.

DEPR:
It has been found that a combination of a hydrocarbon with a bromine source provides a very potent passivating chemistry for fluorine-based etches. For example, one embodiment which has been successfully demonstrated is as follows: The starting structure included a thin film of tungsten. Initial gas flows included 50 sccm of $SF.sub.6$, 5 sccm of $CH.sub.4$, and 15 sccm of HBr, at a total pressure of 250 milliTorr and an applied RF power level of 500 Watts. After the pattern had begun to clear, an additional flow of 20 sccm of $WF.sub.6$ was added, as will be further discussed below. The resulting structure showed nearly vertical etched sidewalls, only slight linewidth erosion, and excellent selectivity to resist.

DEPR:
Another, alternative, family of chemistries for fluoro-etching uses a feed gas mixture which includes a fluorine source such as $SF.sub.6$), plus a bromine source, such as HBr, plus a very weak oxygen source (e.g., carbon monoxide). This chemistry provides anisotropic high rate fluoro-etching with good selectivity to photoresist.

DEPR:
Another, alternative, family of chemistries for fluoro-etching uses a feed gas mixture which includes a fluorine source (such as $SF.sub.6$) plus a fluorosilane

(e.g., SiF.sub.4), plus a bromine source (such as HBr), plus a weak oxygen source such as carbon monoxide. This chemistry provides anisotropic high rate fluoro-etching with good selectivity to photoresist.

DEPR:
Another process which is adapted for use with process module 1300 is a low pressure silicon nitride etch. This etch utilizes a remote plasma gas mixture of SF.sub.6 flowing at 100 sccm and He flowing at 5000 sccm. The substrate has a temperature of 25 degrees C., RF plasma was not generated. The etch rate of the silicon nitride was 37 angstroms per minute. The silicon dioxide was observed not to have etched. An addition source of Fluorine could be used such as F.sub.2, CF.sub.4, or C.sub.2 F.sub.6. These additional sources may reduce the selectivity of the etch to silicon oxide. The etch rate can be increase by the additional use of RF in situ plasma. This process is also useful for GaAs and HgCdTe processing.

DEPV:
4. Removing the native oxides caused by the prior steps utilizing Fluorine chemistry, for example, anhydrous HF technique.

CCOR:
134/1.1

CCXR:
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L6: Entry 8 of 20   File: USPT   Oct 20, 1998

DOCUMENT-IDENTIFIER: US 5824607 A
TITLE: Plasma confinement for an inductively coupled plasma reactor

DEPR:
The evacuation of the interior of the chamber housing 11 is controlled by a
throttle valve 18 on a vacuum line 19 which connects to a vacuum pumping system
21 having one or more vacuum pumps such as a turbomolecular pump.

CCXR:
134/1.1

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L6: Entry 19 of 20   File: USPT   Apr 11, 1989

DOCUMENT-IDENTIFIER: US 4820377 A
TITLE: Method for cleanup processing chamber and vacuum process module

DEPR:
An elevator drive motor 32 provides the elevation of the transfer arm 28, and the
arm drive motor 34 provides the extension and retraction of the transfer arm 28.
Neither of these motors requires a vacuum feedthrough since they are housed
inside the exhaust manifold 36. The manifold 36, as shown in FIG. 1, has a
cylindrical shape and extends from the bottom of chamber 12 downward. The
manifold also extends through and is attached to the bottom of chamber 12 a short
distance into chamber 12. The pump 38 is at the end of manifold 36 away from its
attachment to chamber 12. The motor 26 also extends downward from chamber 12.
Pump 38 can be, for example, a turbomolecular pump. The exhaust manifold 36 does
not open directly into the vacuum load lock chamber 12, but instead has apertures
40 around its top (the end of manifold 36 extending into chamber 12). Thus, the
exhaust manifold 36 is configured so that there is not a line of sight path from
the elevator drive motor 32, the arm drive motor 34, or from the pump 38 to the
vacuum load lock chamber 12. This reduces ballistic transport of particulates
from these moving elements into the load lock chamber. The arrangement shown in
FIG. 1 has been found useful but other arrangements are possible to provide the
necessary transportation of the wafer 48.

CCOR:
134/1.1

CCXR:
134/1

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L6: Entry 15 of 20   File: USPT   Feb 27, 1990

DOCUMENT-IDENTIFIER: US 4904621 A
TITLE: Remote plasma generation process using a two-stage showerhead

DEPR:
An elevator drive motor 32 provides the elevation of the transfer arm 28 and the arm drive motor 34 provides the extension and retraction of the transfer arm 28. Neither of these motors requires a vacuum feedthrough since they are housed inside the exhaust manifold 36. The manifold 36, as shown in FIG. 1 has a cylindrical shape and extends from the bottom of chamber 12 downward. The manifold also extends through and is attached to the bottom of chamber 12 a short distance into chamber 12. The pump 38 is at the end of manifold 36 away from its attachment to chamber 12. The motor 26 also extends downward from chamber 12. Pump 38 can be, for example, a turbomolecular pump. The exhaust manifold 36 does not open directly into the vacuum load lock chamber 12, but instead has apertures 40 around its top (the end of manifold 36 extending into chamber 12). Thus, the exhaust manifold 36 is configured so that there is not a line of sight path from the elevator drive motor 32, the arm drive motor 34, or from the pump 38 to the vacuum load lock chamber 12. This reduces ballistic transport of particulates from these moving elements into the load lock chamber. The arrangement shown in FIG. 1 has been found useful but other arrangements are possible to provide the necessary transportation of the wafer 48.

CCOR:
134/1.2

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L6: Entry 14 of 20   File: USPT   Jun 19, 1990

DOCUMENT-IDENTIFIER: US 4935115 A
TITLE: Method and apparatus for cold sputter cleaning an elongated metal
substrate

DEPR:
The vacuum chambers 2 and 2' are connected to a known vacuum pump 7; whereas the
chambers 3 and 3' are connected to a rotary valve pump 8. The actual working
space or vacuum space 5 is connected to a turbomolecular pump 9. Feed-through
elements 10, 10' of suitable types are present between the atmosphere (pay-off
and take-up stations 1, 6) and the chambers 2, 2'; respectively between the
chambers 2, 3 and 2', 3'. In addition to feed-through elements of the type 10 and
10', there are also hermetically sealable valves 4 and 4' between the chambers 3
and 5 and 3' and 5, respectively.

DEPR:
The operation of the process line is as follows. A vacuum of 10.sup.-1 to
10.sup.-2 Torr is created in the chambers 2 and 2', by means of the roots pump 7,
with a flow rate of 500 m.sup.3 per hour, for instance. A still better vacuum, of
10.sup.-2 Torr or lower, for instance, is created in the chambers 3 and 3', by
means of the pump 8, for instance with a flow rate of 10 m.sup.3 per hour. A high
vacuum, of 10.sup.-4 to 10.sup.-7 Torr for instance, is created in the vacuum
space 5 by means of the turbomolecular pump 9. The valves 4 and 4' are completely
closed while a vacuum is created by pumping in the space 5. When this condition
is reached, the line is ready for cleaning of the long substrate 11 to be started
when the valves 4 and 4' are opened.

DEPR:
A typical embodiment of the vacuum space or vacuum chamber 5.is schematically
represented in longitudinal section in FIG. 2. This vacuum space 5 consists of
three interconnected spaces 12, 13 and 14. The space 12 is provided with
connecting elements 15 for the turbomolecular pump 9, whereas the space 14 is
provided with connecting elements 16 for the supply of an inert gas, such as
argon. The actual apparatus 13 for cleaning the long substrate 11 is inserted
between the vacuum spaces 12 and 14.

CCXR:
134/1

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L7: Entry 1 of 13   File: USPT   Dec 4, 2001

DOCUMENT-IDENTIFIER: US 6325861 B1
TITLE: Method for etching and cleaning a substrate

BSPR:
Thereafter, the etchant residue on the etched substrate is removed by exposing
the substrate in a process zone to an activated cleaning gas comprising
halogen-substituted saturated hydrocarbon gas, oxygen gas, and nitrogen gas.
Preferably, the halogen-substituted saturated hydrocarbon gas comprises a ratio
of saturated hydrocarbon groups to halogen species of from about 1:2 to about
4:1. The volumetric flow ratio of halogen-substituted saturated hydrocarbon gas
to oxygen gas is sufficiently high to remove substantially all the etchant
residue on the substrate. In a preferred embodiment, the cleaning gas comprises
CH_3F, O_2, and N_2, the volumetric ratio of CH_3F to O_2
being from about 1:5 to 2:1.

DEPR:
Spent etchant gas and etchant byproducts are exhausted from the etching chamber
30 through an exhaust system 90 comprising one or more roughing pumps and
turbomolecular pumps and which is capable of achieving a minimum pressure of
about 10^{-3} mTorr in the etching chamber 30. Typically, a throttle valve 95
is provided in the exhaust for controlling the pressure in the etching chamber
30.

DEPR:
Preferably, the halogen-substituted saturated hydrocarbon gas serves as a source
of hydrocarbon radicals and halogen radicals to the process environment. The
methyl radicals upon being activated or energized, combine with metallic species
in the etchant residue to form metal-substituted hydrocarbons that are volatile
and gaseous and can be easily exhausted from the chamber. For example, activated
or energized CH_3F gas combine with aluminum or titanium in the etchant
residue, in the following reactions:

DEPR:
The halogen-substituted saturated hydrocarbon gas also preferably comprises a
relatively high ratio of saturated hydrocarbon groups to substituted halogen
species because the desired selectivity to silicon dioxide requires a low
fluorine environment. Preferably, the ratio of saturated hydrocarbon groups to
substituted halogen species is at least 1:2, and more preferably from about 1:1
to 4:1. Suitable halogen-substituted saturated hydrocarbon gases that have a high
ratio of saturated hydrocarbon groups to halogen species, comprises gases such as
for example, CH_3F, CH_3Cl or CH_3Br, all of which have a ratio of
hydrocarbon groups to halogen species of about 1:1.

DEPR:
A preferred halogen-substituted saturated hydrocarbon gas for removing etchant
residue from etching a SiO_2 dielectric layer 18 over an aluminum layer 16
comprises CH_3F gas, because the fluorine species in the gas is highly
reactive to silicon-containing etchant residue. Also, the fluorine species does
not chemically attack or otherwise degrade the exposed portions of the underlying
metal layer, especially when the underlying layer 120 contains aluminum. This is
especially surprising because the CH_3F gas is typically used for depositing
etchant residue in the form of sidewall deposits (commonly known as sidewall
polymer) on the etched features. For example, CH_3F is commonly used during
metal etching processes to serves as a source of free carbon species to enhance
the deposition of an inhibitor or passivator layer. Thus, it was unexpected to
discover that the CH_3F gas can also be used to remove or etch away the
etchant residue, especially when the etchant residue is composed of elemental

metal or metal compounds in an amorphous or polymer matrix.

DEPR:
The volumetric flow ratio of halogen-substituted saturated hydrocarbon gas to oxygen gas is selected to remove all of the metal-containing and silicon-containing components in the etchant residue. The ratio of the metal species, silicon components, and hydrocarbon can vary in the amorphous etchant residue depending on the type of material that was previously etched and the composition of the resist material and/or etchant gas. The substrate 5 is exposed to an activated cleaning gas comprising a volumetric flow ratio of halogen-substituted saturated hydrocarbon gas to oxygen gas to nitrogen gas that is sufficiently high to remove substantially all the etchant residue on the substrate without requiring a post etch wet solvent cleaning step. When halogenated hydrocarbons are used to etch vias in a dielectric layer, such as for example, a layer of silicon oxide, silicon nitride, or polyimide (low K dielectric layer) on the substrate 5, a suitable volumetric flow ratio of halogen-substituted saturated hydrocarbon gas to oxygen gas (the ratio of CH_3F to O_2) that removes substantially all the etchant residue from the substrate is from about 0.25 to about 2, and more preferably from about 0.75 to about 1.5.

DEPR:
Preferably, the cleaning gas further comprises a non-reactive gas, such as N_2 or Ar, to further reduce or limit etching of the exposed portions of the dielectric layer, and to improve the etching selectivity of the cleaning process to the dielectric layer. The nitrogen gas also serves to transport saturated hydrocarbon radicals past the substrate 5 surface to maximize the percentage of reactive or active gas species that react with the substrate. The volumetric flow ratio of inert gas to the other cleaning gas components is selected to enhance etching selectivity without detrimentally affecting the rate of removal of the etchant residue, by excessive dilution of the cleaning gas composition. Preferably, the volumetric flow ratio of CH_3F to N_2 is from about 1 to about 4, and more preferably from about 1.2 to about 2.

DEPR:
Thereafter, the substrate was transported by the robotic arm 50 to the RPS chamber. In a cleaning step, the etchant residue was removed by exposing the substrate 5 for 60 seconds to an activated cleaning gas comprising 200 sccm CH_3F , 200 sccm O_2, and 150 sccm N_2. The microwave generator was maintained at a power level of 1000 Watts and the chamber at a pressure of 1500 mTorr. In a second step, the remnant resist 15 on the substrate 5 was stripped by a 30 second exposure to an activated stripping gas comprising 30 sccm CF_4, 970 sccm O_2, and 100 sccm N_2, maintained at a pressure of 700 mTorr and powered by a microwave generator operated at a power level of 1400 Watts. In both steps, the substrate 5 was maintained at a temperature of $100.degree.$ C. by flowing helium at a pressure of about 8 Torr behind the substrate 5. Thereafter, the substrate 5 was rinsed by immersing the substrate in deionized water for 5 minutes.

DEPR:
Example 3 demonstrates that increasing the flow rate of CH_3F in the etchant residue cleaning step adversely affects the cleaning process by failing to remove the etchant residue on the substrate 5. In this example, the volumetric flow rate of CH_3F in the cleaning step was doubled from 200 sccm, as in Example 1, to 400 sccm. The remainder of the process parameters were the same as that of Example 1. SEM micrographs taken of the substrate 5 processed in this example reveal etchant deposits remaining at the bottom of the via hole and incomplete removal of the remnant resist 15. This demonstrates the importance of the volumetric flow ratio of CH_3F, O_2, and N_2 in the cleaning process step.

DEPR:
In Example 4, the volumetric flow rate of all cleaning gases in the cleaning step were doubled (as compared to example 1) to the following flow rates 400 sccm CH_3F, 400 sccm O_2, and 300 sccm N_2. The remainder of the process parameters, including the pressure of the cleaning gas in the cleaning chamber, remained the same as that of Example 1. SEM micrographs taken of a substrate 5 processed according to this example, revealed etchant deposits at the bottom of the via holes and incomplete removal of the remnant resist 15. This experiment

indicates that the volumetric flow rates, and not just the volumetric flow ratios, are important to the process.

DEPL:
Some of these volatile species, such as $(CH_3)_3 Al$, have relatively low condensation temperatures and can condense or otherwise redeposit material on the substrate 5, and should be rapidly exhausted from the chamber 35 to prevent their re-condensation onto the substrate. The energized halogen-substituted species of the saturated hydrocarbon gas, such as <u>fluorine</u> species, react with the silicon-containing components of the etchant residue 10 to form volatile gaseous species, such as SiF_4, which are also exhausted from the chamber 35.

CLPR:
1. A method of cleaning a substrate, the method comprising exposing the substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas, oxygen gas, and nitrogen gas, wherein the halogen-substituted saturated hydrocarbon gas consists essentially of one or more of CH_3 <u>F,</u> CH_3 Br, or CH_3 Cl, and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon gas to oxygen gas is from about 1:5 to about 2:1.

CLPR:
4. A method according to claim 1 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of CH_3 <u>F.</u>

CLPR:
5. A method of cleaning a substrate, the method comprising exposing the substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas and oxygen gas, wherein the halogen-substituted saturated hydrocarbon gas consists essentially of CH_3 <u>F,</u> and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon gas to oxygen gas is from about 1:5 to about 2:1.

CLPR:
12. A method according to claim 9 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of one or more of CH_3 <u>F,</u> CH_3 Br, or CH_3 Cl.

CLPR:
13. A method according to claim 12 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of CH_3 <u>F.</u>

CLPR:
16. A method of cleaning a substrate, the method comprising exposing the substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas and oxygen gas, whereby the activated cleaning gas removes etchant residue on the substrate, wherein the etchant residue comprises a metal species, and wherein the halogen-substituted saturated hydrocarbon gas consists essentially of one or more of CH_3 <u>F,</u> CH_3 Br, or CH_3 Cl, and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon gas to oxygen gas is from about 1:5 to about 2:1.

CLPR:
18. A method according to claim 16 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of CH_3 <u>F.</u>

CLPR:
23. A method according to claim 19 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of CH_3 <u>F.</u>

CLPR:
28. A method of cleaning a substrate, the method comprising exposing the substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas and oxygen gas, wherein the halogen-substituted saturated hydrocarbon gas consists essentially of one or more of CH_3 <u>F,</u> CH_3 Br, or CH_3 Cl, and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon gas to oxygen gas is from about 1:6 to about 2:1.

CLPR:
32. A method of cleaning a substrate, the method comprising exposing the

substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas and oxygen gas, wherein the halogen-substituted saturated hydrocarbon gas comprises one or more of CH.sub.3 F, CH.sub.3 Br or CH.sub.3 Cl, and wherein the halogen-substituted saturated hydrocarbon gas consists essentially of one or more halogen-substituted saturated hydrocarbon compounds comprising a ratio of saturated hydrocarbon groups to substituted halogen species of at least 1:2, the volumetric flow ratio of the halogen-substituted saturated hydrocarbon compounds to oxygen gas being from about 1:5 to about 2:1.

CLPR:
36. A method according to claim 32 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of one or more of CH.sub.3 F, CH.sub.3 Br, or CH.sub.3 Cl.

CLPR:
37. A method according to claim 36 wherein the halogen-substituted saturated hydrocarbon gas consists essentially of CH.sub.3 F.

CLPR:
38. A method of cleaning a substrate, the method comprising exposing the substrate to an activated cleaning gas comprising (i) one or more halogen-substituted saturated hydrocarbon compounds having a ratio of saturated hydrocarbon groups to substituted halogen species of at least 1:2 and (ii) oxygen gas, wherein the one or more halogen-substituted saturated hydrocarbon compounds having a ratio of saturated hydrocarbon groups to substituted halogen species of at least 1:2 consists essentially of one or more of CH.sub.3 F, CH.sub.3 Br, or CH.sub.3 Cl, and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon compounds to the oxygen gas is from about 1:5 to about 2:1.

CLPR:
42. A method according to claim 38 wherein the halogen-substituted saturated hydrocarbon compounds consists essentially of one or more of CH.sub.3 F, CH.sub.3 Br, or CH.sub.3 Cl.

CLPR:
43. A method according to claim 42 wherein the halogen-substituted saturated hydrocarbon compounds consists essentially of CH.sub.3 F.

CLPV:
a first step of exposing the substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas consisting essentially of one or more of CH.sub.3 F, CH.sub.3 Br or CH.sub.3 Cl and oxygen gas, and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon gas to oxygen gas is from about 1:5 to about 2:1; and

CLPV:
(c) exposing the substrate to an activated cleaning gas comprising halogen-substituted saturated hydrocarbon gas and oxygen gas, the halogen-substituted saturated hydrocarbon gas consisting essentially of one or more of CH.sub.3 F, CH.sub.3 Br, or CH.sub.3 Cl, and wherein the volumetric flow ratio of the halogen-substituted saturated hydrocarbon gas to oxygen gas is from about 1:5 to about 2:1; and

CCOR:
134/2

CCXR:
134/21

CCXR:
134/26

CCXR:
134/30

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L7: Entry 3 of 13   File: USPT   Nov 23, 1999

DOCUMENT-IDENTIFIER: US 5988187 A
TITLE: Chemical vapor deposition system with a plasma chamber having separate
process gas and cleaning gas injection ports

EXP:
Smith; Lynette F.

BSPR:
The residue coats the walls of the chamber, and also tends to clog the gas
injection ports. The chamber, as well as the gas injection ports, needs to be
cleaned periodically. This ensures that each wafer encounters the same
environment so that the deposition process is repeatable. Since opening up the
chamber (changing out the hardware) for cleaning is very labor intensive and
costly, a method for removing the deposition from the chamber walls without
opening the chamber itself has been previously developed. This "insitu" cleaning
has been accomplished in the past using fluorine. The fluorine is injected into
the chamber as NF.sub.3. Fluorine is known to etch silicon and silicon dioxide at
high rates when it is accompanied by ion bombardment. Radio frequency (RF) power
provides the energy for ion bombardment, with the NF.sub.3 serving as the source
of fluorine.

BSPR:
The RF power is applied to the chamber and NF.sub.3 is injected into the chamber.
The walls will then be cleaned of oxide deposition. However, there may still be a
significant amount of fluorine in the chamber and on the walls and free
particles. For this reason, a pre-deposition conditioning step is often required.
The conditioning step is essentially a deposition that getters the fluorine and
tacks down particles onto the chamber walls. When this pre-deposition
conditioning step is completed, the cover wafer is transported back to its
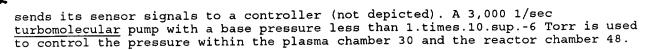cassette and the next wafer can then be processed.

BSPR:
As stated earlier, the insitu cleaning gas is designed to chemically etch the
SiO.sub.2 (silicon dioxide) residue. However, high pressure caused by supersonic
gas flows in front of the jet screws causes regions of scarce fluorine radicals
that reduce fluorine induced etching of the SiO.sub.2. FIG. 2 a schematic
depiction of a detail of a jet screw. NF.sub.3 gas is injected into the chamber
14 through the jet screw 16. Within the jet screw, there is SiO.sub.2 clogging,
schematically depicted at point 18 at the jet screw 16. The high pressure region
20 of scarce fluorine radicals caused by the supersonic gas flows in front of the
jet screws 16 reduces the fluorine induced etching of the SiO.sub.2 in this area,
and in particular, prevents the jet screws 16 from being unclogged of the
SiO.sub.2 residue. All of the other chamber surfaces are typically cleaned except
for the jet screw ports.

BSPR:
By re-routing of the cleaning gas through a separate, second gas injection port,
the pressures within the jet screws are equalized with the pressure of the
chamber. This allows higher fluorine dissociation and SiO.sub.2 etching.

DEPR:
An electrostatic chuck is provided to hold the wafers within a reactor chamber
48. The use of an electrostatic chuck obviates the need for mechanical clamping
of the wafer. Wafer cooling is provided by helium, for example, to the underneath
or backside of the wafer through a helium supply line 50. Closed-loop control of
the helium pressure regulates the wafer temperature during deposition. Insitu
wafer temperature monitoring is provided through a temperature probe 52 which

sends its sensor signals to a controller (not depicted). A 3,000 1/sec
turbomolecular pump with a base pressure less than 1.times.10.sup.-6 Torr is used
to control the pressure within the plasma chamber 30 and the reactor chamber 48.

DEPR:
Once the cover wafer is in place, the RF power is applied to the plasma chamber
30 and the NF.sub.3 cleaning gas is injected in the plasma chamber 30 through
port 60. After the walls of the chamber 30 and the jet screw port 62 have been
cleaned of oxide deposition, there is still a fair amount of fluorine in the
chamber 30 and on the walls, as well as free particles. For this reason, a
pre-deposition conditioning step may be used. The conditioning step is
essentially a deposition that getters the fluorine and tacks down particles. When
this pre-deposition conditioning step is completed, the cover wafer is then
transported back to its cassette and the next wafer can then be processed.

CCOR:
134/22.1

CCXR:
134/1.1

CCXR:
134/22.18

CCXR:
134/31

CCXR:
134/37